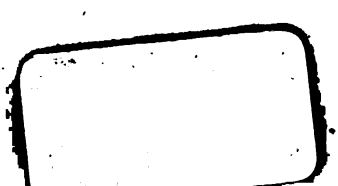

INSTITUTES

OF

MATHEMATICAL

GEOGRAPHY.

For the Use of Schools.

BY THOMAS HOGG,

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"Ex elementis constant, ex principiis
"oriuntur, omnia."

Truro:

PRINTED AT THE CORNISH PRESS,
BY J. TREGONING.

1806.

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1.

A POINT has situation in space or quantity, but has no parts, and no magnitude.

2.

A straight line is the shortest distance between two points.

3.

Parallel lines lie equally distant from each other, and, if infinitely produced, would never coincide.

4.

A circle is a figure the area of which is limited by one continued curved line called its circumference, and is such that all the straight lines, which can be drawn from a point within it, called its centre, to the circumference, are equal to one another.

5.

The diameter of a circle is a straight line which passes from one extremity to the other, through the centre.

6.

A semicircle is that part included between the diameter and half the circumference.

7.

A quadrant is half a semicircle, or one quarter of a circle.

8.

The circumference of every circle is divided into 360 equal parts, called degrees; each degree is supposed to be divided into 60 equal parts, called minutes; each minute is supposed to be subdivided into 60 seconds, &c. Hence, a semicircle contains 180, a quadrant 90, and half a quadrant 45, degrees.

The divisions of a circle are de-

noted by characters, thus, 10° 24′ 44″ 36‴, &c. which signify, ten degrees, twenty four minutes, forty four seconds, thirty six thirds, &c.

9.

An angle is formed by the inclination of two lines to one another, and the point of intersection is called the angular point.

10.

Every angle contains as many degrees, minutes, &c. as are contained in that portion of a circle which is intercepted between the sides: the angular point of which is the centre of the circle, and the number of degrees, minutes, &c. thus intercepted, is the measure of the angle.

11.

The extent of a circle does not alter the number of its degrees, neither are the degrees, which an angle contains, increased by the extent of its sides; hence, the degrees, minutes, &c. of a circle become enlarged in proportion to its magnitude.

12.

A globe, or sphere, is formed by the revolution of a semicircle round its diameter which remains fixed, and is such that all the straight lines, that can be drawn from its surface to its centre, are equal to one another.

13.

The superfices of the terrestrial globe represents the parts of the earth

in their respective places, in the same proportion which the superfices of the globe bears to that of the earth. The *political* divisions, viz. empires, kingdoms, principalities, &c. although they have originated from accidental causes, are considered as permanent; under the *physical* division, the globe is considered as terraqueous, the solid parts being divided into continents, islands, peninsulas, &c. The fluid, into oceans, seas, straits, &c. And, under the *mathematical*, the earth is considered as divided into parts by human ingenuity, and thereby fitted to become the subject of a science.

14.

The rod, about which the globe

revolves, represents the axis of the earth; the extremities of the axis are the poles which are under the two points in the heavens about which the stars seem to revolve; the one is called the north; the other, the south pole.

15.

The circles of the globe are of two kinds, viz. great, and small. A great circle divides the globe into two equal parts, the centre of which coincides with that of the globe. A small circle is parallel to a greater; hence, it divides the globe into two unequal parts, and its centre is different from that of the globe.

16.

The principal great circles are

The Horizon;

The Meridian;

The Equator;

The Ecliptic;

The Equinoctial colure;

The Solstitial colure.

17.

The *Horizon.*

The principal points on the horizon are the north and south, at which it is cut by the meridian; and the east and west, which are equidistant from the former. It contains five concentric circles: the innermost contains the degrees of amplitude, numbered from the east and west points, and

which proceed each way to 90°. The next circle contains the degrees of azimuth, numbered from the north and south towards the east and west. The next contains the thirty two points of the compass. It is divided into four quadrants, each of which is subdivided into eight parts, so that a point occupies 11¼ degrees.

18.

The fourth circle upon the horizon is divided into the twelve signs of the zodiac, each of which is subdivided into 30 degrees; and the fifth contains the calendar of days and months. These two circles constitute a perpetual table by which the sun's place may be found for any given day.

19.

The horizon divides the globe into the upper and lower hemispheres; in this sense it is called the rational horizon, in contradistinction to that circle which terminates the view, where the earth and sky seem to meet, and which is called the sensible horizon.

20.

A horizontal line is either real, and is parallel to the rational; or imaginary, and is parallel to the sensible, horizon. A vertical line intersects the horizontal in such a manner as to fall directly upon it.

21.

The *Meridian.*

The principal points of the meri-

dian are the north and south poles, at which the globe is fixed; the zenith, and the nadir, which are also called the poles of the horizon; the former being directly over the head of the spectator, and the latter directly under his feet.

22.

The meridian is divided into quadrants at the equator and the poles. On the upper side the degrees are numbered from the equator to the poles, to shew the distance of any point from the equator; on the under side they are numbered from the poles to the equator, for finding the distances of points from the

poles, or for the more readily rectifying the globe.

23.

The meridian divides the globe into the eastern and western hemispheres, and its poles are the east and west points of the horizon.

24.

Meridians are 24 semi-circles terminating in the poles, and cutting the equator at right angles. Every place is supposed to have its meridian; hence, if we move eastward or westward, we change our meridian.

25.

All places lying under the same semi-circle have the same meridian, and the semi-circle opposite to it is

called the lower meridian. All places which are under the same meridian have noon at the same time, and consequently all other hours.

26.

The *Equator.*

The most remarkable point on the equator is that, at which it is cut by the meridian of London, which coincides with one of the equinoctial parts, at which it is divided into two points, each being 180°. These begin at the first meridian, and are numbered both ways round the globe, to shew how far a point is east or west from London.

27.

The equator is also divided into 24

equal parts, called hours, and they are subdivided into minutes; and, as the quotient of 360, divided by 24, is 15, an hour is equal to 15°, and a degree occupies the space of four minutes of time.

28.

The equator is every where 90° distant from each pole. It divides the globe into the northern and southern hemispheres, and its poles are the same as those of the world.

29.

The *Ecliptic.*

The principal points on the ecliptic are the equinoctial, at which it cuts the equator; the one is at the beginning of Aries, the other at Libra;

and the solstitial, which are the points of it at the greatest distance from the equator; the one is at the beginning of Cancer, the other at Capricorn.

30.

The ecliptic is divided into quadrants at the equinoctial and solstitial points. It is also divided into twelve equal parts, called signs, each of which contains 30°.

The twelve signs, and their characters are as follows:

Aries, ♈

The sun enters this sign on the 20th of March, which is the vernal equinox.

Taurus, ♉

Gemini, ♊

Cancer, ♋

The sun enters this sign on the 21st of June, which is the summer solstice.

Leo, ♌

Virgo, ♍

Libra, ♎

The sun enters this sign on the 23d of September, which is the autumnal equinox.

Scorpio, ♏

Sagittarius, ♐

Capricornus, ♑

The sun enters this sign on the 21st of December, which is the winter solstice.

Aquarius, ♒

Pisces, ♓.

31.

The first six are called northern signs, because they possess that half of the ecliptic which is north from the equator; the rest are called southern signs, as being south from the equator. Capricornus, Aquarius, Pisces, Aries, Taurus, and Gemini, are the ascending signs; and Cancer, Leo, Virgo, Libra, Scorpio, and Sagittarius, the descending.

32.

The *Equinoctial Colure.*

The meridian which passes through the first of Aries and Libra is called the equinoctial colure. Its poles are the two points where the solstitial colure cuts the equator.

33

The *Solstitial Colure.*

The meridian which passes through the first of Cancer and Capricorn is called the solstitial colure. Its poles are the two points where the equinoctial colure cuts the equator.

34.

The most remarkable of the small circles are four, viz.

The Tropic of Cancer,

The Tropic of Capricorn,

The Arctic Circle, and

The Antarctic Circle; which are all parallel to the equator.

35.

The *Tropics.*

The tropic of cancer touches the ecliptic at the beginning of cancer,

which is the point of its greatest northern declination, or 23° 29′ north from the equator. The tropic of capricorn touches the ecliptic in the first degree of that sign, which is the point of its greatest southern declination, or 23° 29′ south from the equator.

36.

The *Polar Circles.*

The polar circles are those which the poles of the ecliptic seem to describe by the diurnal revolution of the earth; they are therefore at the same distance from the poles as the tropics are from the equator.

37.

The horary circle is fixed to the

northern part of the brass meridian, so that the centre of the circle coincides with the north pole of the globe which carries the index. It is divided into twice twelve hours; the upper XII answers to noon, the lower to midnight.

38.

The quadrant of altitude is a flexible slip of brass which can be applied to the surface of the globe for measuring distances. When screwed to the vertical point of the meridian it shews the altitude of objects above the horizon, &c. It is divided into 90° and the divisions go 18° below the horizon.

39.

The latitude of a place is its distance north, or south from the equator, and is reckoned upon the two upper quadrants of the meridian.*

40.

Parallels of latitude are circles drawn parallel to the equator, at the distance of 10° from it on each side to the poles.

41.

The difference of latitude, between two places, is the distance between

---

* As the ancients knew more of the habitable world from east to west, than from north to south, they applied the term "Longitudo" to the distances of places lying in the former direction, and "Latitudo" to those lying in the latter.

the parallels of latitude that pass through them, reckoned on the meridian.

42.

Longitude is the distance of the meridian of any place from the first meridian, and is reckoned upon the equator, either east, or west from the first meridian.*

---

* The first meridian is that which passes through some remarkable place, from which longitude is estimated. The ancients reckoned eastward from the meridian passing through the most western part of the then known world. About A. D. 140. Ptolemy first computed by longitude and latitude. His first meridian passed through the Canary Islands. In the year 1634, Lewis XIII commanded the French to reckon from that which passes through the island Ferro. Now, in ge-

43.

The difference of longitude of two places is the distance between the points in which the meridians passing through them cut the equator.

44.

All places between the equator and the north pole are in north latitude; and all places between the equator and the south pole are in south latitude; hence, the greatest extent of latitude is 90°.

45.

In geography we are supposed to

---

neral, each country makes its first meridian to pass through its capital, hence, on English globes, it passes through London, or more properly through Greenwich Observatory.

look towards the north; hence, all places on the right of the first meridian are in east longitude: and all places on the left in west longitude. The greatest extent of longitude is 180°.

46.

There is no latitude at the equator, as both poles are in the horizon, and from it latitude is estimated; and there is no longitude at the first meridian, because there longitude begins; hence, that point of the equator, through which the first meridian passes, has neither latitude nor longitude.

PROBLEM I.

To find the Latitude of a Place.

Bring the place under the graduated

side of the brass meridian, and the degree directly above it is its latitude. Thus the latitude of the Lizard is 49° 57′ north, and that of Lima 12° south.

PROB. II.

To find the Longitude of a Place.

Bring the place to the meridian, and that degree of the equator, reckoned from the first meridian, which is below the graduated edge, is the longitude. Thus, the longitude of Falmouth is 5° 5′ west, and that of Constantinople 29° east.

PROB. III.

The Latitude and Longitude being given to find the Place.

Find the longitude on the equator,

and bring it to the meridian; then find the latitude on the meridian, and under it will be the place. Suppose the latitude 18° N. and the longitude 76° 48′ W.; the place is Kingston, Jamaica.

PROB. IV.

To find the difference of Latitude between two Places.

If they lie in the same hemisphere, bring each to the meridian, and observe where they intersect it. Subtract the less from the greater, and the difference will be that required. Thus, the difference of latitude between Kingston and St. Petersburg, is 41° 56′.

If they lie on different sides of the

equator, add the two latitudes, and the sum will be the difference. Thus, the difference between London and Lima, is $63\frac{1}{2}°$.

PROB. V.

To find the difference of Longitude between two Places.

Bring each of the places successively to the meridian, and mark where they cut the equator; the number of degrees between the marks will be the difference of longitude required. Thus, the difference of longitude between the North Cape, 26° E., and the Lizard, $5\frac{1}{2}$ W., is $31\frac{1}{2}°$.

PROB. VI.

To find the difference of Time between two Places.

Bring one of the places to the me-

ridian, set the index of the horary circle to XII, then bring the other place to the meridian; the number of hours between twelve, and that to which the index now points, is the difference of time between the two places. Thus, the difference, in time, between Rome and Bombay, is 4 hours, 3 minutes.

PROB. VII.

The difference of Time between two Places being given, to find their Longitude.

Suppose it is 2 o' clock, P. M. at London, it will be $12\frac{1}{2}$ P. M. at Kamschatka; the difference being $10\frac{1}{2}$ hours. Fifteen degrees upon the equator correspond to one hour in

time; therefore $12\frac{1}{4}$ hours are equal to $157\frac{1}{2}°$, the difference of longitude between the two places.

PROB. VIII.

To find the distance between two Places.

If they lie under the same meridian, bring them to the graduated side of the brass meridian, and mark the number of degrees intercepted between them; which, if multiplied by 60, will give the distance in geographical; and, if multiplied by $69\frac{1}{2}$, will give it in English miles.

If they lie under the equator, bring them successively to the meridian, and mark their difference in longitude. But, if they lie neither under the same meridian, nor under the equator, lay

the quadrant of altitude over them, so that the beginning of the degrees be at one of them, and it will shew their distance. To reduce the distance to geographical or English miles, multiply as before.

47.

The earth, in consequence of its great distance from the heavens, is so small, that the sensible and rational horizons are made to coincide without any sensible error.

48.

Every place has its own proper horizon; but the wooden horizon represents that of any place, when it is brought to the zenith; then its situation, in respect of the wooden hori-

zon, is similar to that which the place on the earth has; that is, the place is equally distant from every part of the horizon. This is called rectifying the globe.

PROB. IX.

To rectify the Globe for any Place.

Find the latitude, reckon as many degrees from the nearest pole on the lower side of the meridian, and bring that degree to the horizon; then reckon the same number of degrees as the latitude from the equator towards the elevated pole, and that point will be in the zenith.

PROB. X.

To find how any place lies from you.

Rectify the globe for the place, and

fix the quadrant of altitude directly above it, then bring the quadrant through the other place to the horizon, and it will show the point towards which the place is situated. Thus, Rome lies S E.; and Pondicherry, in the East Indies, due E. from London.

49.

The celestial bodies are seen to come above the horizon on the east, and to set in the west; so that they seem to go round the earth in 24 hours.

50

At the vernal equinox the sun rises due east, goes westward above the equator, and sets due west: next day he rises a little northward of

the east, goes along a line parallel to the equator, and sets a little northward of the west, and thus continues to advance northward a little every day, until the summer solstice, when he goes along the tropic of Cancer. He then advances southward, a little every day, until the autumnal equinox, when he goes along the equator. After which he crosses the equator, and advances gradually southward until the winter solstice, when he goes along the southern tropic; he then returns northward, and arrives at the equator on the 20th of March.

51.

As the equator is divided into equal parts by the horizon, the sun when

in the equator, will be twelve hours above, and twelve below the horizon; hence, the days and nights are then equal.

52.

When the globe is rectified for any place in N. L. every parallel on the north side of the equator will be divided into two unequal parts, of which the greater is above the horizon; hence, when the sun is in the northern signs, the days are longer than the nights; and, when in the southern, the nights are longer than the days. It is also evident that he continues longest above the horizon, when at the tropic of Cancer; and longest below, when at the tropic of Capricorn.

53.

When the globe is rectified for any place in S. L. every parallel on the south side of the equator will be divided into two unequal parts; and when the sun is in the southern signs the days are longer than the nights, and shorter when he is in the northern. The longest day happens when he is at the tropic of Capricorn, and the shortest when he is at the tropic of Cancer.

54.

It is noon when the sun is either vertical, or directly south, or north, from any place; therefore a place lying to the eastward will have the sun in the meridian sooner than a

place more westerly; and, as the sun goes 15° every hour, when it is noon at London, it will be 1 P. M. at a place 15° eastward of it, and 11 A. M. 15° westward of it.

PROB. XI.

To know what o'clock it is in any part of the world at any time.

Bring the place where you are to the meridian, set the index of the horary circle to the given time, and turn the globe till the other place come to the meridian; the index will shew the hour. Thus, if it be 3 P. M. at London, it will be 8 h. 22 m. P. M. at Madras; and 9 h. 53 m. A. M. at Jamaica.

55.

The globe is divided into five zones

by the tropics and polar circles, viz. the torrid, two temperate, and two frigid zones. The torrid zone lies between the tropics, and extends nearly $23\frac{1}{2}^{\circ}$ on each side of the equator. The northern temperate zone lies between the tropic of cancer and the arctic circle; the southern temperate zone lies between the tropic of capricorn and the antarctic circle, each of which is 43° broad. The northern frigid zone lies within the arctic, and the southern within the antarctic circle, each of which is 47° broad.

56.

The equator passes through the southern part of the isle of St. Thomas, Ethiopia, the Indian Ocean,

the middle of Sumatra and Borneo, the Pacific Ocean, Quito, the northern extremity of Peru, the northern mouth of the Amazon, and the Atlantic Ocean.

57.

In the torrid zone lie a great part of Africa, Arabia Felix, great part of Madagascar, the Arabian Sea, part of India, the isles of the Indian Sea, the Sandwich Islands, Peru, Brasil, Jamaica, great part of the Atlantic Ocean, St. Helena, &c.

58.

The tropic of cancer passes through the great Sandy Desert of Africa, the middle of Lybia, the Red Sea beyond Mount Sinai, the middle of Arabia,

enters the Arabian Sea, goes through Cambay, India, the southern parts of China, the north Pacific Ocean, the Gulf of Mexico, touches the Island Cuba, and returns through the Atlantic to the western shore of Africa.

59.

The tropic of capricorn passes over the Tongue of Africa, the southern part of Madagascar, New Holland, the south Pacific Ocean, Peru, the southern parts of Brasil, and the south Atlantic Ocean.

60.

In the north temperate zone lie all Europe, almost all Asia, great part of N. America, and of the Atlantic and Pacific Oceans.

61.

In the south temperate zone lie part of Africa, the Cape of Good Hope, Straits of Magellan, the southern parts of S. America, and great part of the Atlantic, Indian, and Pacific Oceans.

62.

The arctic circle passes through the northern parts of Iceland, Swedish, and Russian Lapland, great part of Russia, Berring's Strait, Mackenzie-River, where it is 300 yards wide, and 300 feet deep, Davis's Strait, and Greenland.

63.

In the N. frigid zone lie the northern parts of Iceland, Spitbergen, Nor-

wegian, Swedish, and Russian Lapland, Nova Zembla, Samojedi, and Baffin's Bay.

The southern frigid zone, according to the latest discoveries, exhibits nothing but innumerable islands and fields of ice.

64.

The sun is vertical twice in the year at every place within the tropics, once when he is going northward, and again when he returns towards the equator. He is vertical at the equator on the 20th of March, and the 23d of September. He is vertical once in the year at the tropics, viz. at the tropic of cancer on the 21st of June, and at the tropic of capricorn

on the 21st of December. He is never vertical at any place without the tropics.

65.

For some days, within the polar circles, the sun neither rises, nor sets; and the more are those days, the nearer the place is to the poles; so that at the pole he sets not for half a year, and rises not all that time.

66.

The sun's declination is his distance from the equator, north, or south, reckoned on the meridian. At the equinoxes he has no declination; and at the solstices his declination is $23\frac{1}{2}°$.

67.

The analemma is a scale which

contains the year divided into months and days, and by which the sun's declination may be determined. Thus to find the sun's declination for the 19th of October; bring the meridian exactly over the analemma, and the declination will be found to be 10° south.

68.

The sun's declination is equal to the latitude, either south, or north; hence when he is vertical at a place, he is as far from the equator as the place is.

69.

About the time of the solstices, the days increase and decrease very slowly, because at the tropics the eclip-

tic is nearly parallel to the equator; hence, for some days before and after the solstices the change in the sun's declination is very small. About the time of the equinoxes the days increase and decrease very fast, because the angle made by the ecliptic with the equator is greatest; hence, the change in the sun's declination is then greatest.

PROB. XII.

To find the sun's place in the Ecliptic.

Look for the day of the month on the horizon, and opposite to which, in the circle of signs, will be found the sun's place in the ecliptic. Thus, on the 21st of June, he is in the first degree of cancer; and on the 15th

of November he is in the 24th degree of scorpio.

PROB. XIII.

To find the sun's declination.

Find the sun's place in the ecliptic for the given day, bring it to the meridian, and the degree exactly over it is the declination, thus on the 5th of August his declination is 17° N.

PROB. XIV.

To find at what place the sun is vertical

Bring the place to the meridian, set the index of the horary circle to XII, and find the latitude; then turn the globe, and observe the sign and degree of the ecliptic which comes to the meridian; find that sign and degree on the

horizon, and the day of the month will be opposite; then bring the place where you are to the meridian, and the index will shew the time when the sun is vertical at the given place.

PROB. XV.

To find where the sun is vertical at any given time.

Having found the sun's declination, bring the place for which the hour is given to the meridian, and set the index to the given hour; turn the globe till the index point to the upper XII, and the place under the sun's declination on the meridian has the sun at that hour in its zenith. Thus, if it be asked at Truro where the sun is vertical on the 8th of August at

four P. M. it will be found to be at St. Cruz, or at St. Christopher.

70.

The solar rays extend 90° every way; hence, at the equinoxes both poles are enlightened. When the sun is 20° north from the equator, his light goes 20° beyond the north, and does not reach the south pole, and, as he appears to go round the earth in that parallel, he will not set at those places which are within 20° of the north, and will not shine at those within 20° of the south pole.

71.

The limits of the places round the poles, where the sun never sets at one time, and never rises at another, are

at the same distance that the sun is from the equator; and, when he begins to shine constantly at a place, his declination is equal to the distance of the place from the pole, and on the same side of the equator; and when it is continually dark his declination is equal to the distance of the place from the pole, but on the other side of the equator.

72.

The sun rises at the north pole on the 20th of March, and does not set until the 23d of September, upon which day he rises at the south pole, where he shines continually until the 20th of March; hence, the poles have half a year of day, and half a year of darkness.

PROB. XVI.

To find when the sun begins to shine continually at a place, from the vernal to the autumnal equinox.

Bring the place to the meridian below the pole; mark the degree above it; reckon the same number of degrees from the equator towards that pole; turn the globe till the side of the ecliptic, in which the sun is when advancing towards that pole, comes below the degree reckoned to, and the point below it is the sun's place; opposite to which, on the horizon, will be found the time when the sun begins to shine continually.

Bring the other side of the ecliptic in which the sun is, when receding

from the pole, below the degree on the meridian, and it will shew when continual day-light ends. Thus, the North Cape will be found to be 19° from the pole; therefore, reckon 19° N. declination, bring the first quarter under it, and continual day-light will be found to begin on the 15th of May: bring the second quarter below it, and continual day-light will be found to end on the 28th of July. After this, for some months, the sun rises and sets every 24 hours.

To find when continual darkness begins;---Reckon the degrees on the other side of the equator, and bring the side of the ecliptic, which recedes from the pole, below the degree rec-

koned to: then bring the side, in which the sun advances, below the same degree, and it will shew when continual darkness ends. Thus, find 19° S. declination; bring the third quarter of the ecliptic below it, and continual darkness will be found to begin on the 17th of November: if the fourth quarter be brought below, continual darkness will be found to end on the 25th of January, after which the sun rises and sets, for a considerable time, every 24 hours.

73.

An arch of the horizon, intercepted between the east and west points, and that point at which he sets, is called

the sun's amplitude; and it increases with the latitude of the place.

PROB. XVII.

To find the time of the sun's rising and setting, to any amplitude not exceeding $66\frac{1}{2}°$.

Rectify the globe for the given place; find the sun's place in the ecliptic, and bring it to the meridian; set the index of the horary circle to XII; then bring the sun's place to the east side of the horizon, and the index will shew the time of sun-rising; bring his place to the west side, and the index will shew the time of his setting.

Double the hour of sun-setting, and it will give the length of the day;

and the hour of his rising, and it will give the length of the night. Thus, on the 1st of May, at London, the sun rises 40 minutes past 4, and sets 20 m. past 7; therefore, the length of that day is 14 h. 40 m. and the remainder, the length of the night.

PROB. XVIII.

To find on what point of the horizon the sun rises.

Rectify the globe, bring the sun's place, for the given day, to the east side of the horizon, and opposite to it will be found the distance of the point, at which he rises, from the east, and likewise the point of the compass. Thus, on the 18th of July, the sun

rises at Falmouth $34\frac{1}{2}°$ from the east, towards the north, or N. E. by E.

74.

The sun's azimuth is his distance from the north, or south points; and his altitude is his height above the horizon. To rectify the globe for the zenith is to fix the quadrant of altitude to the given latitude on the meridian, reckoned from the equator.

PROB. XIX.

To find the sun's Azimuth and Altitude.

Rectify the globe, bring the sun's place to the meridian, and set the index to XII, turn the globe till the index point to the given hour. Rectify the globe for the zenith, bring

the quadrant over the sun's place to the horizon, and number the degrees on the horizon between it and the S. or N. points. Thus, on the 7th of August at 8 o' clock A. M. at London, the sun is $76\frac{1}{2}°$ from the S. towards the E., which is his azimuth.

To find his altitude.---Reckon the degrees on the quadrant between the horizon and the sun's place, in the ecliptic, and the degree of the quadrant cut by the sun's place is the altitude required; thus, that on the above given day is $31\frac{1}{2}°$.

75.

Twilight begins and ends when the sun is depressed 18° in the perpendicular below the horizon; if the sun's

place, when the globe is rectified, does not come 18° below the horizon, there is no twilight at the given place.

If the latitude be above 48° the sun's place will not rise 18° above the horizon for several nights about the summer solstice, and then there is no total darkness at that place.

In higher latitudes the twilight is of longer duration, till in latitude 66½ there is no twilight, but continual day; as there the sun, when lowest, touches the edge of the horizon.

PROB. XX.

To find when twilight begins.

Rectify the globe, bring the sun's place to the meridian, and set the in-

dex to XII; fix the quadrant of altitude at the latitude of the given place; then find the point of the ecliptic directly opposite to the sun's place, and turn the globe till it be 18° above the west side of the horizon, so will his place be 18° below the east side, and the index will shew when twilight begins.

76.

The earth performs its diurnal revolution, from west to east, in about 24 hours; which produces the day and night, and makes all the heavenly bodies to have an apparent motion from east to west, round the earth, in the same time.

77.

The earth performs its annual revolution round the sun in a year, from west to east, in the ecliptic; this motion produces the difference in the length of the days and nights, and the regular succession of the seasons.

78.

The ecliptic is an astronomical circle, and peculiar to the celestial globe; it divides the heavens into the northern and southern hemispheres: it has the sun in its centre, and the earth goes round its circumference. It is exhibited upon the terrestrial globe that problems relating to the sun may be solved on it.

79.

The axis of the earth forms with the plane of the ecliptic an angle of $66\frac{1}{2}°$: and the plane of the equator makes with the plane of the ecliptic an angle of $23\frac{1}{2}°$.

80.

In consequence of the annual revolution of the earth, if a star rise or set with the sun, it will, in a short time, rise or set before him; because, his apparent place in the heavens will be removed east from the star; hence, stars, which, at one season, set with the sun, at other times, rise when he sets and shine until the morning.

81.

The earth, when on one side of the

ecliptic, is 190 millions of miles distant from the opposite part, but, as it is about 95 millions of miles distant from the sun, the fixed stars do not appear nearer at one time than at another; hence, the poles of the earth are always considered as pointing towards the same stars.

82.

The earth, at the summer solstice, is on the south side of the sun. The north pole points to a star $66\frac{1}{2}^{\circ}$ above him, and the tropic of Cancer is opposite to him; hence, the days on the north side are longer than those on the south side of the equator; also, the whole northern frigid zone is enlightened, and the solar rays do not

reach any part of the southern polar circle.

83.

At the winter solstice the earth is north from the sun; the south pole is directed to a point $66\frac{1}{2}°$ below him, and the tropic of Capricorn is directly opposite to him; hence, the days, on the south side, are longer than those on the north side, of the equator: also the whole southern frigid zone is enlightened, and the northern is in darkness.

84.

At the equinoxes the equator is opposite to the sun, and the poles equally distant from him; hence, the days and nights are equal at every place

on the globe. At other times the poles are inclined to the sun, and the difference in the length of the days is in proportion to the difference of that inclination.

85.

Let the globe be rectified for the sun's declination, and the horizon will represent that circle which separates the enlightened hemisphere from that which is in darkness.

PROB. XXI.

To find those places at which the sun is rising or setting, and those at which it is noon or midnight.

Rectify the globe for the sun's declination, bring the place given to the meridian, place the index at the

given hour, and turn the globe till it point to XII. To all those places under the upper half of the meridian it is noon; to those at the lower, it is midnight. The sun is rising at all the places in the western half, and setting at those in the eastern half, of the horizon; all the places in the upper hemisphere have day, and those in the lower have night.

86.

A natural year consists of 365 days, 5 hours, 49 minutes; the sun in his apparent annual motion describes an ellipsis whose focus is out of its centre: the time in which he passes through the northern signs is longer than that in which he passes through

the southern; consequently, he is in the former while the earth describes the greatest part of its orbit.

87.

The sun is about 187 days in passing from the first degree of Aries to the first degree of Libra, and about 179 in passing from the first of Libra to Aries; therefore our summer is longer than our winter; and, if the north pole be brought to the zenith, it will appear that the enlightened part of the year, there, exceeds the darkened about eight days.

88.

The difference between the length of the days and nights, near the equator, is inconsiderable; at the tropic of

Cancer there are two hours difference, and all places in the same parallel have their days equal; hence, the difference between the longest and shortest days is in proportion to the distance from the equator.

89.

A climate is the space included between two parallels of latitude, and is so constituted that the length of the longest day, in one, exceed that of the longest day in the other, by half an hour.

90.

Climates, as known to the ancients, do not exhaust the surface of the globe, but are terminated by the polar circles; because between the polar

circles and the poles the length of the longest day, in one parallel, exceeds that of the longest in the next, by a month.

91.

There are 24 climates between the equator and each of the polar circles. In the end of the first the length of the day is $12\frac{1}{4}$ hours long; that of the second, thirteen hours, &c. each increasing half an hour, to latitude $66\frac{1}{4}°$.

PROB. XXII.

To find the Climates.

Rectify the globe for any parallel of latitude, and find the length of the longest day in a given place; then elevate the globe till the length of the

longest day in the next parallel exceed that of the longest day in the former by half an hour; all the space, included between the two parallels, constitutes a climate.

92.

The inhabitants of the earth are distinguished by the situation of their shadows at noon into Amphiscii, Heteroscii, and Periscii. The Amphiscii live in the torrid zone; their shadows, at noon, are one part of the year south, and another part, north of them; and, as they have, twice in the year, the sun in the zenith when they have no shadow at noon, they are also called Ascii.

them the same phenomena, and their seasons are the same; but all their hours are opposite, for when it is midday with the one, it is midnight with the other.

98.

The Antipodes are diametrically opposite, *i. e.* they live in places which differ 180°, or 12 hours in longitude; the one has north, and the other as much south latitude; hence, the heavenly bodies rise to the one when they set to the other; the day of the one is the night of the other; when the one has the longest, the other has the shortest day: and, when it is midsummer to the one, it is mid-winter to the other.

PROB. XXIII.

A place being given to find its Antœci, Periœci, and Antipodes.

Find the latitude of the place, bring it to the meridian, and the antœci will be found in the same latitude on the other side of the equator. Set the index to the upper XII, and turn the globe till it come to the lower XII; the place under the meridian, in the same latitude with the given place, is the periœci. In this position the antipodes are under the same point of the meridian where the antœci were before.

99.

The solar is nearly six hours more than the civil year: if the earth begin

its revolution at the commencement of our year, it will be nearly six hours longer in finishing it; and in four revolutions it will be nearly a day longer than four years; these hours, thus accumulated, are added to the end of February every fourth year, which is called bissextile, or leap-year.

100.

By the addition of these four times six hours, leap-year is eleven minutes too long; and these minutes, in somewhat more than 130 years, make a day: in 1800 years they will amount to eleven days; and these, in England, were taken from September, A. D. 1752; hence, the beginning of the present year, old

style, is 12 days later than it is, new style.

101.

If the year be not an exact century, divide it by four; if nothing remain, it is leap-year; if there be a remainder, it denotes the number since last leap-year. If the year be an exact century, cut off the two cyphers, and divide by four; if there be no remainder it is leap-year; if there be a remainder, annex two cyphers, and it will shew the number of years since last century leap-year.

102.

The moon is about 240,000 miles distant from the earth; she completes a revolution in 29½ days, and, being

an opaque body, shines by reflecting the solar light: the plane of her orbit, extended, cuts the ecliptic in two opposite points, which are called her nodes, and her greatest distance from the ecliptic is about five degrees.

103.

When in either of her nodes the moon is in the ecliptic; at other times, she is in north or south latitude. She is invisible when on the same side of the earth with the sun; when on the opposite, she is full; and, when at the same distance from the sun with the earth, she is called quarter moon: between the new moon and the quarters, her convex side is towards the sun; and, between full and quarter

moon, she appears like a circle deficient on one side.

104.

The moon always presents nearly the same side to the earth; because, she performs her revolution round her axis in the same time that she moves round the earth. The former motion is equable and uniform; the latter, unequal and irregular.

105.

An eclipse of the sun is caused by the interposition of the moon, between him and the earth; and can only happen at new moon, and when she is in, or near, one of her nodes, *i.e.* in, or near, the plane of the ecliptic:

then her shadow will intercept part of the solar light.

106.

An eclipse of the moon is caused by her falling into the shadow of the earth; and this can only happen when she is full. As the sun and the earth are always in the plane of the ecliptic, lunar eclipses only happen when the moon is in, or near, the ecliptic.

107.

The plane of the moon's orbit is inclined to that of the earth; consequently, when in conjunction or opposition, the moon is sometimes above, and sometimes below, the ecliptic; hence, eclipses do not happen at every new and full moon. If she be

above 13° from the node, there cannot be a lunar eclipse; and, if she be above 17° from the node, her shadow will fall northward, or southward of the earth, and there will be no eclipse of the sun.

PROB. XXIV.

The day and hour being given, to find all those places where a lunar eclipse will be visible.

Find the place to which the sun is vertical at the given hour, rectify the globe to that place, and bring it to the upper part of the meridian: at whatever place the sun is then vertical, the moon must be vertical to its antipodes; and, as the sun will be visible to every place above the horizon, the

moon will be visible to all those below, at the time of her greatest obscuration.

108.

As eclipses of the moon frequently continue a long time, they may be seen in more than one hemisphere; because, by the earth's diurnal motion, she will rise in several places after the eclipse has begun.

109.

As the moon is much smaller than the earth, and as her shadow is conical, because she is less than the sun, a small part of the earth can only be obscured during a solar eclipse: her shadow passes over the earth at the rate of 2000 miles per hour; hence,

solar. eclipses are very local and of short duration.

110.

As the moon completes her revolution round the earth in 29½ days, there will be 12 moons and 11 days in a year; therefore, if it be new moon on the first of January in any year, she will be 11 days old on the 1st of January next year, 22 days old the year after, &c. all which variations will be finished in nineteen years, when she will again change on the 1st of January.

111.

This revolution of nineteen years is called the *moon's cycle*, or the *golden number*. The first year of the

christian æra was the second of this cycle; hence, if to the current year we add one, and divide the sum by 19, the remainder will be the golden number: if nothing remain, 19 is the golden number.

112.

The moon's age, on the 1st of January, is called the *epact:* to find which, multiply the golden number by 11, and the product, if less than 30, is the epact; if greater, divide it by 30, and the remainder is the epact.

113.

To the number of months from March inclusively add the epact of a given year, if the sum be less than 30, subtract if from 30; if greater, sub-

tract if from 60, and the remainder will be the day of the month on which the new moon falls.

114.

If the moon change on the 1st of January, in common years, she will be $1\frac{1}{2}$ day old on the 1st of February, will change on the 1st of March, and will be $1\frac{1}{2}$ day old on the 1st of April, two days on the 1st of May, &c. which is found by continually adding the excess of the month above $29\frac{1}{2}$ days, which are called the numbers for the months; hence, to find the *moon's age*, add the epact, the number for the month, and the day of the month, and reject the complete moons in the amount.

115.

The moon performs a revolution about the earth, from any one point in the zodiac to the same, in 27 days, 7 hours, 43 minutes, which is a periodical month: a synodical month is the time in which she passes from one conjunction to another, viz. 29½ days; hence, a synodical is about 2 days 5 h. longer than a periodical month.

116.

While the moon is passing from one conjunction to another, the sun, in consequence of the earth's annual motion in its orbit, will be apparently advanced towards the east, so that when the moon comes round to that part of the heavens where the sun was

at the former conjunction, it will not be then in conjunction, but will have such a portion to describe as, when added to the periodical month, will make it 29 days, 12 hours, 44 minutes.

117.

The moon moves at the rate of nearly 13° every day: the sun does not go quite 1°; therefore, the moon will leave the sun nearly 12° every day; and as, at the change, the moon is in the same point of the ecliptic with the sun, the moon's place may be found, by first finding the sun's place, and then by counting 12° forward for every day of her age.

PROB. XXV.

To find the time when the Moon rises.

Rectify the globe, bring the sun's place to the meridian, and set the index to XII; then find the moon's place in the ecliptic, and bring it to the east side of the horizon; the index will shew the time of her rising: bring her place to the meridian, and the index will shew the time of her southing.

118.

To find the time of the moon's southing:---when she is 12° east of the sun, or one day old, she is 12° east of the meridian when the sun is on it: by the diurnal revolution of

the earth she moves 12° in 49 minutes; hence, she will be that time later in coming to the meridian on any day, than she was on the preceding. Multiply her age by 49, and divide the product by 60, which will give the hour and minute when she comes to the meridian, afternoon.

119.

About the autumnal equinox, when at, or near the full, the moon rises almost at the same hour, for several nights: this phænomenon is called the *harvest moon.*

PROB. XXVI.

To account for the Harvest Moon.

At the autumnal equinox the sun is in the 1° of Libra; the point oppo-

site is the 1° of Aries, which is the moon's place, she being then full; and, as both are in the equator, she will rise when the sun sets, which is at 6 o'clock. As the moon advances 12° every day, next night she will be in the 12° of Aries. Rectify the globe for the latitude, bring the sun's place, which is now the 2° of Libra, to the meridian, and set the index to XII: turn the globe till the moon's place, viz. the 12° of Aries, cut the eastern side of the horizon, and the index will be found to point nearly to 6 o'clock, at which the moon rose on the preceding night.

In the same manner it may be shewn that, for several nights, before

and after the full, she rises nearly at the same time.

120.

At the autumnal equinox, the moon, being in the ascending signs, apparently, in her nocturnal course, describes a parallel of the equator one night much nearer the north pole than another, and in a fortnight, when she appears above the horizon, she passes from the southern to the northern tropic: and, as the heavenly bodies come sooner above the horizon the nearer it is to the north pole, in every lunation, while the moon is passing from the tropic of Capricorn to that of Cancer, some minutes are to be deducted from those by which she

would rise later each night, if the plane of her orbit were to coincide with that of the equinoctial; and as much is to be added while she passes from the tropic of Cancer to that of Capricorn: likewise, something must be added, in the former case, to the time at which she would set; and, in the latter, a like quantity must be deducted.

121.

The sun, about the autumnal equinox, is in, or near Libra, and the moon, when full, in the ascending signs; hence, full moons, at that time, rise very little later the one than the other: in spring the new moons, for several successive nights, rise near-

ly at the same time, while there is a greater difference between the rising of the full moons than at any other time; because, in spring the moon, when new, is in the ascending, and, when full, in the descending signs.

122.

As the axis of the earth is perpendicular to the plane of the equator, and as its diurnal revolution is equable, equal portions of the equinoctial appear to pass the meridian in equal divisions of time; but, as the ecliptic is oblique both to the plane of the equator and the axis of the world, the sun cannot revolve from one meridian to the same again in 24 equal hours; but he will sometimes be sooner, and

later at others, because equal portions of the ecliptic pass the meridian in unequal parts of time.

PROB. XXVII.

To shew the equation of time.

Begin either at Aries or Libra, and mark the equator and the ecliptic at every tenth degree: turn the globe, and the marks, in the first quadrant of the ecliptic, will come sooner to the meridian than the corresponding marks of the equator; those of the second quadrant will come later; those of the third, sooner; and those of the fourth, later: but, those at the beginning of each quadrant will come to the meridian at the same time with those of the equator.

123.

A well regulated clock keeps equatorial time; therefore, while the sun is in the first and third quadrants, an accurate sun-dial ought to be faster than the clock; and, while he is in the second and fourth, the dial ought to be slower: at the beginning of each quadrant they ought to be equal.

124.

The moon is the principal agent in causing tides: the sun has also an influence upon the waters, but, from his immense distance, it is inconsiderable. If his power be considered as three, we consider that of the moon as ten.

125.

As the moon revolves in her orbit from west to east, she comes to the meridian of any place about three quarters of an hour later than she did on the preceding day; hence, there are two flood, and two ebb tides, in about twenty-five hours.

126.

When the sun and moon are in conjunction, or in opposition, the tides proceed from their united powers, which are considered as thirteen; they then rise to a more than ordinary height, and are called spring tides.

127.

When the moon is in her first or

last quarter, the sun, being in the meridian when she is in the horizon, counteracts her influence, and depresses the water where she raises it; hence, neap tides then take place.

128.

About the time of the equinoxes when the moon is in conjunction or opposition, the sun's influence coincides with hers, and, therefore, the tides rise higher then than at any other time: and, as the earth is nearer the sun before he comes to the verna. equinox, than when at the equinox, the tides, which happen a little before the vernal equinox, are the highest: and, as the earth is nearer the sun, a little after he has passed the

autumnal equinox than when at the equinox, the tides, which happen after the autumnal equinox, are the highest.

129.

The highest tides are not on the day of new, or full moon, but two or three days afterwards: for the influence of the luminaries upon the waters on the day of the new, or full moon, being superadded to their actions on the preceding days, makes their influence superior to the single action of that day.

PROB. XXVIII.

The latitude, the sun and moon's place, and the time of high water being given, to find the moon's azimuth.

Rectify the globe, bring the sun's

place to the meridian, and set the index to the upper XII; find the moon's longitude and latitude,* and there make a mark; turn the globe till the index point to the given time; fix the quadrant of altitude in the zenith, and lay it over the moon's place, then will the arch in the horizon, intercepted between the meridian, and the point where it is cut by the quadrant, shew the azimuth.

PROB. XXIX.

The latitude, the sun and moon's place, the moon's azimuth when it is high water being given, to find the hour.

Rectify the globe for the latitude and zenith, set the index to the upper

* By an ephemeris.

XII; find the moon's place, and make a mark there; put the quadrant to the given azimuth, and turn the globe till the moon's place come under it; the index will shew the hour.

PROB. XXX.

The time of high water, at new and full moon, being given, to find the time of high water for any given day.

Rectify the globe, find the sun's place and bring it to the meridian, set the index to the upper XII; find the moon's place, and make a mark there; turn the globe till it come to the meridian, and the index will shew the time of the moon's southing; add that to the time of high water at the full and change, and the sum will be

the time of high water for the given day.

If the sum exceed twelve hours, 12 must be subtracted from it, and the remainder will be the time of high water, next morning.

130.

The time of high water is about 52 minutes later every day, and when the time of high water, at the full and change, is known, the time of any other flood tide may be thus reckoned:

The earth moves 15° every hour, the moon's diurnal motion, 13°, wants two of it; the tides are 52 minutes later every day, answering to the 13°; hence, if it be high water at 12 o'clock

on Monday, it will be high water on Tuesday, at 52 minutes past 12; on Wednesday, at 44 minutes past 1; on Thursday, at 36 minutes past 2; on Friday, at 21 minutes past 3; on Saturday, at 20 minutes, past 4; on Sunday, at 12 minutes past 5; &c.

131.

At new and full moon, it is generally high water upon the most westerly shores of Europe, about 3 hours after the moon has passed the meridian; it then diverges into different parts; the body of the stream flows along the west and north of Ireland, continues through the Hebrides, passes the north of Scotland between the Orkney Islands and Shet-

land, and through the Pentland Frith, eastward of which it flows in confluence with a set from the northward along the whole eastern shores of Great Britain; so that it is high water progressively later at every intermediate point towards the south.

132.

One branch of the main tide flows up the English Channel, and continues its course nearly to Dungeness, where it is met by the northern tide, which, from its superior weight, prevails over it, and flows an hour longer to the westward: from this conflux the tide rises several feet higher in the strait than at any other place in the Channel.

133.

The *celestial globe* represents the concave arch of the heavens, and, when using it, we conceive ourselves at its centre. It is divided into three regions, viz. the zodiac, the northern hemisphere, and the southern hemisphere.

134.

The zodiac is 16° broad, in the middle of which is the ecliptic; it includes the latitudes of the planets; beyond its limits neither the moon nor the planets ever move. The zodiacal constellations are known by the name of the twelve signs.

135.

There are thirty eight constellations

in ths northern hemisphere, and forty seven in the southern. A straight line drawn through the two stars of Ursa Major, (Charles' wain,) called the *pointers*, leads to the pole star.

136.

The latitude of a star is its distance, north or south, from the ecliptic, upon which, longitude is reckoned from that circle which passes through the first of Aries: the latitude and longitude of the stars are found by the quadrant of altitude.

PROB. XXXI.

To find the latitude and longitude of a star.

Bring the pole of the ecliptic to the meridian, and fix the quadrant over

it; lay its graduated edge over the star; and the point above the star is its latitude: the sign and degree of the ecliptic, reckoned from the first of Aries, is its longitude; thus, the latitude of Arcturus is 31° N.; and the longitude of Capella, 70°.

137.

The declination of a star is its distance, north or south, from the equinoctial, measured on the brass meridian; thus, the declination of Sirius is 16° 27′ S.

138.

As the figure of the earth is spherical, places lie, either under the equinoctial, under the poles, or between both: from this difference of situation,

the heavens, in their apparent diurnal motion, with respect to the inhabitants, exhibit very different phænomena.

139

To those who live under the equinoctial, the poles lie in the horizon; the equator, tropics, and polar circles are perpendicular to the horizon; the heavenly bodies rise and set perpendicularly, and their days and nights are always equal. The globe, thus situated, is called a *right sphere.*

140.

To those who live under the poles the axis of the world is at right angles to the horizon; the equator and horizon coincide, and to them the four lesser circles are parallel; the poles

are in the zenith and nadir; there is but one day and night throughout the year; the moon in half her monthly course never rises, and in the other never sets; the fixed stars always describe circles parallel to the horizon, some of whieh never rise, and others never set. The globe, thus situated, is called a *parallel sphere*,

141.

To those who live neither under the equinoctial, nor under the poles, the equator and all its parallels make oblique angles with the horizen; one of the poles of the world is elevated above, and the other depressed below, the horizon. This situation of the globe is called an *oblique sphere*.

142.

The right ascension of the sun, (or a star,) is that degree of the equinoctial, which is cut by the meridian, when it is brought to it; and it is reckoned from the first of Aries, eastward, round the globe; thus, the right ascension of Aldebaran is 66° 6′.

PROB. XXXII.

To find the right ascension of a star in time.

Make the globe into a right sphere; bring the given star to the eastern side of the horizon; and the place, where the equinoctial is cut by it, will shew its right ascension in time; thus, the right ascension of Arcturus is 14 h. 5 min.

143.

Oblique ascension is an arch of the equinoctial intercepted between the first of Aries and that point of the equinoctial which rises with the sun, moon, or any star.

Ascensional difference is that which exists between right and oblique ascension.

144.

At the equinoxes the right and oblique ascension of the sun are equal. When the right ascension is greater than the oblique, the sun rises before 6 o'clock; and, when the oblique is greater, he rises after six.

PROB. XXXIII

To find the sun's right and oblique

ascension, and the ascensional difference.

Rectify the globe for the given place; find the sun's right and oblique ascension; subtract the less from the greater; bring the remainder into time, and it will shew when the sun rises before, or after 6 o'clock.

PROB. XXXIV.

To find the azimuth and altitude of a fixed star.

Rectify the globe for the given latitude, and the sun's place; turn the globe till the index point to the given hour; fix the quadrant of altitude in the zenith; lay it over the star, and it will shew its altitude and azimuth.

PROB. XXXV.

The azimuth of a star being given to find the hour of the night.

Rectify the globe for the given latitude and the sun's place; if the star be due N. or S.; bring it to the meridian, and the index will shew the hour :---if it be in any other direction, fix the quadrant in the zenith, and bring it to the star's azimuth in the horizon; turn the globe till the quadrant cut the star, and then the index will shew the hour.

PROB. XXXVI.

To find the time of the rising, culmi-

nation, (or meridian transit,) and setting of a star.

Rectify the globe for the latitude and the sun's place, for the given day; turn the globe till the star be upon the eastern side of the horizon, and the index will point to the time of its rising: bring the star to the meridian, and the index will shew the time of its culmination; thus, by turning the globe till it come to the western side of the horizon, the index will shew the time of its setting. Thus, at London, on the 17th of November, the Pleiades rise at three-quarters past 3 o'clock, P. M. culminate at midnight, and set a little past 8, A. M.

The appearance of the heavens may be represented on the celestial globe, by first rectifying it, and bringing the sun's place to the meridian, and setting the index to the upper XII; after which, nothing else is required, but to place the poles exactly north and south, and to turn the globe till the index point to any given hour: then, conceiving ourselves at its centre, the part of the globe above the horizon will be a true representation of the heavens.

By forming a clear conception of these "Institutes" the Student will be enabled to understand more extensive and scientific works, and eventually, it is presumed, he will not find it difficult to enter upon the study of the most definite part of Natural Philosophy---ASTRONOMY.